Claims

1. A processing system capable of electronically generating reverberation signals having a decay rate, the system comprising:

(A) a notchpass filter for receiving a signal and generating an output signal, comprising:

a first module for delaying the signal by a first delay value;

a first multiplier for scaling the signal according to a first gain; and

a second multiplier for scaling the signal according to a second gain,

where the first module and first and second multipliers are operatively coupled to form a first signal processing circuit path,

the notchpass filter having a comb filter-like amplitude and delay output response characterized by a plurality of delay maximum at certain frequencies and a plurality of gain minimum at said certain frequencies;

(B) an energy transmission network for receiving the output signal from the notchpass filter, the energy transmitting network comprising:

a second module for delaying the signal by a second delay value; and

a third multiplier for scaling the signal according to a third gain,

where the second module and third multipliers are operatively coupled to form a second signal processing circuit path that both delays and scales the received signal;

the values of the first and second gain have a defined relationship with the first and second delay values and the third gain; and

the combined notchpass filter and energy transmitting network have an amplitude output response characterized by a plurality of gain minimum at the same frequencies and a plurality of delay maximum at the same frequencies so that the decay rate is substantially identical at all frequencies.

2. A method for electronically generating reverberation signals having a decay rate, the method comprising:

(A) providing a notchpass filter in combination with an energy transmission network where the notchpass filter comprises:

a first module for delaying the signal by a first delay value;

a first multiplier for scaling the signal according to a first gain; and

a second multiplier for scaling the signal according to a second gain;

the first module and first and second multipliers operatively coupled to form an signal processing circuit path,

the notchpass filter having a comb filter-like amplitude and delay output response characterized by a plurality of peak delay maximum at certain frequencies and decreased gain minimum at the same certain frequencies;

the energy transmitting network comprising:

a second module for delaying the signal by a second delay value;

a third multiplier for scaling the signal according to a third gain; and

the second module and third multipliers operatively coupled to form an signal processing circuit path that both delays and scales the received signal;

(B) calculating modified first and second gain value from the first and second delay values and the first, second and third gain; and

(C) applying the modified first and second gain value to the first and second multipliers, respectively, so that, in response to modified first and second gain, the combined notchpass filter and energy storing network has an amplitude output response characterized by a plurality of gain minimum at the same certain frequencies and a plurality of delay maximum at the same certain frequencies so that the decay rate is substantially identical at all frequencies.

3. A modulation mixer capable of electronically generating reverberation signals from a signal comprising:

(A) a first plurality of “n” number of inputs for receiving a plurality of “n” number of signals representing an input vector;

(B) a second plurality of “m” number of inputs for receiving a plurality of “m” number of randomization signals, from a source of continuously changing signals, for modulating the “n” number of signals representing an input vector;

(C) a plurality of “n” number of outputs for generating a plurality of “n” number of modified signals representing a processed output vector;

(D) a converter for converting the "m" number of randomization signals into n^2 number of coefficients such that the energy in the output vector is substantially identical to the energy in the input vector for all possible values of the "m" number of signals; and

(E) a mixer multiplication module for multiplying the "n" number of signals representing the input vector by the plurality of n^2 number of coefficients to form the plurality of "n" number of modified signals representing the processed output vector.

4. The modulation mixer of claim 3 further comprising:

(E1) a source of continuously changing randomization signals coupled to the plurality of "m" number of inputs.

5. The modulation mixer of claim 4 wherein the source of continuously changing randomization signals comprises a plurality of low frequency random phase signal generators.

6. The modulation mixer of claim 4 wherein the source of continuously changing randomization signals comprises a plurality of periodic phase signal generators each having different frequencies.

7. The modulation mixer of claim 6 where the phase of only one of the plurality of periodic phase signal generators changes at a given instant and when the phase stops changing another phase signal begins to change.

8. The modulation mixer of claim 7 further comprising:

(E2) a sequencer coupled to the plurality phase signal generators for controlling the stopping and starting of the plurality phase signal generators such that each phase signal changes until reaching a value substantially close to one of 45 degrees, 135 degrees, 225 degrees and 315 degrees and thereafter stops changing and the phase signal of another of the plurality of periodic phase signal generators begins to change.

9. The modulation mixer of claim 3 further comprising:

(F) an energy transmission network having "n" number of inputs coupled to the "n" number of outputs of the output vector and further having "n" number outputs, the energy transmission network containing a plurality of delays and where the "n" number of outputs of the energy transmission network are coupled to the "n" number of inputs of the input vector to form a feedback loop.

10. The modulation mixer of claim 9 where the energy transmission network comprises at least one notchpass filter.

11. The modulation mixer of claim 9 wherein the energy transmission network comprises an acoustic space and further comprising a first plurality of "n" number of acoustic signal transducers having signals derived from the output vector and a second plurality of "n" number of acoustic signal transducers having signals used to derive the input vector.

12. The modulation mixer of claim 3 where the converter comprises:

(D1) a plurality of trigonometric function generators each of which receive one of the "m" number of randomization signals and generate one of the n^2 number of coefficients such that a trigonometric relationships exists between said one randomization signal and said one coefficient.

13. A signal processing system comprising:

a first delay module for creating an output signal;

a first multiplier for scaling the output signal with a first gain;

a second multiplier for scaling the output signal, modified by the first gain, with a second gain; and

a filter formed from the first delay module, the first multiplier, and the second multiplier for creating a comb filter-like amplitude and delay output response characterized by a plurality of peak delay maximum at certain frequencies and decreased gain minimum at the same certain frequencies.

14. The signal processing system of claim 13 in serial combination with an energy transmission network for processing a signal, the energy transmission network comprising:

a second delay module capable of creating a second output; and

a third multiplier for scaling the second output by a third gain, where the second delay module and the third multiplier are operatively coupled to form a third output signal.

15. The processing system of claim 14 wherein a portion of the second output signal is processed and filtered.

16. A plurality of the processing systems of claim 15 coupled in parallel with a source signal.

17. A plurality of the processing systems of claim 15 coupled in series with a source signal.

18. The processing system of claim 14 in combination with one or more filters with frequency responses having one of increased and decreased gain at certain frequencies.

19. The processing system of claim 14 wherein a first filter is coupled in series with the second delay module and a second filter is combined with one of the first and second multipliers.

20. The processing system of claim 13 further comprising:

a second delay module, in series with the first delay module, for delaying the signal by the first delay value;

the first multiplier configured in parallel with the first module in a feedback circuit path; and

the second multiplier configured in parallel with the second delay module in a feedforward circuit path.

21. A reverberation system comprising:

(A) an "n" number of energy dispersive transmission networks each comprising:

(A1) a notchpass filter capable of receiving an input signal and generating a first output signal, the notchpass filter comprising a first delay module for creating a line of poles and zeros, where for every pole located left of an imaginary y axis in an s-plane representation, there is a corresponding zero in the right half plane of the s-plane representation at a same imaginary frequency and the zeros are closer to the imaginary y axis than the poles;

(A2) a second delay module capable of receiving the first output signal generated by the notchpass filter and generating a second output signal; and

(A3) a multiplier capable of scaling the second output signal according to a gain to generate a third output signal, an energy decay rate of the third output signal relative to the input signal being substantially identical at all frequencies; and

(B) a mixer capable of combining the "n" number of third output signals from the "n" number of energy dispersive transmission networks with at least one input signal to form an "n" number of new input signals for supplying to the "n" number of energy dispersive transmission networks.

22. A reverberation system comprising:

(A) a notchpass filter capable of receiving an input signal and generating a first output signal, the notchpass filter comprising a first delay module for creating a line of poles and zeros, where for every pole located left of an imaginary y axis in an s-plane representation, there is a corresponding zero in the right half plane of the s-plane representation at a same imaginary frequency and the zeros are closer to the imaginary y axis than the poles;

(B) a second delay module capable of receiving the first output signal generated by the notchpass filter and generating a second output signal;

(C) a multiplier capable of scaling the second output signal according to a gain to generate a third output signal, an energy decay rate of the third output signal relative to the input signal being substantially identical at all frequencies; and

(D) an feedback adder capable of adding the third output signal to the input signal to generate a new input signal.

23. A energy dispersive transmission network comprising:

(A) a notchpass filter capable of receiving an input signal and generating a first output signal, the notchpass filter comprising a first delay module for creating a line of poles and zeros, where for every pole located left of an imaginary y axis in an s-plane representation, there is a corresponding zero in the right half plane of the s-plane representation at a same imaginary frequency and the zeros are closer to the imaginary y axis than the poles;

(B) a second delay module capable of receiving the first output signal generated by the notchpass filter and generating a second output signal; and

(C) a filter network capable of generating a third output signal from the second output signal; an energy decay rate of the third output signal relative to the input signal having ripple free characteristics minimized at all frequencies.

24. A energy dispersive transmission network comprising:

(A) a notchpass filter capable of receiving an input signal and generating a first output signal, the notchpass filter comprising a first delay module for creating a line of poles and zeros, where for every pole located left of an imaginary y axis in an s-plane representation, there is a corresponding zero in the right half plane of the s-plane representation at a same imaginary frequency and the zeros are closer to the imaginary y axis than the poles;

(B) a second delay module capable of receiving the first output signal generated by the notchpass filter and generating a second output signal; and

(C) a multiplier capable of scaling the second output signal according to a gain to generate a third output signal, an energy decay rate of the third output signal relative to the input signal being substantially identical at all frequencies.

25. The energy dispersive transmission network of claim 24 wherein the gain is provided by a filter.

26. A signal processing system comprising:

a first delay module;

a first multiplier, coupled to the first delay module, capable of creating a real frequency line of poles; and

a second multiplier, coupled to the first delay module, capable of creating a real frequency of the line of zeros;

where for every pole located left of an imaginary y axis in an s-plane representation, there is a corresponding zero in the right half plane of the s-plane representation at a same imaginary frequency and the zeros are closer to the imaginary y axis than the poles.

27. A signal processing system comprising:

a first delay module capable of creating a real frequency line of poles; and

a second delay module capable of creating a real frequency of the line of zeros;

where for every pole located left of an imaginary y axis in an s-plane representation, there is a corresponding zero in the right half plane of the s-plane representation at a same imaginary frequency and the zeros are closer to the imaginary y axis than the poles.

28. A filter comprising:

a delay module capable of creating a line of poles and zeros, where for every pole located left of an imaginary y axis in an s-plane representation, there is a corresponding zero in the right half plane of the s-plane representation at a same imaginary frequency; and

the zeros are closer to the imaginary y axis than the poles.

29. A filter comprising:

a delay means for delaying a signal and for creating a line of poles and zeros, where for every pole located left of an imaginary y axis in an s-plane representation, there is a corresponding zero in the right half plane of the s-plane representation at a same imaginary frequency; and

the zeros are closer to the imaginary y axis than the poles.

30. A signal processing system comprising:

a first means for delaying a first signal and for creating a line of poles;

a second means for delaying a second signal and for creating a line of zeros; and

where for every pole located left of an imaginary y axis in an s-plane representation, there is a corresponding zero in the right half plane of the s-plane representation at a same imaginary frequency and where the zeros are closer to the imaginary y axis than the poles.

31. A signal processing system comprising:

first means for delaying a signal;

a first multiplier means, coupled to first means for delaying a signal, for creating a real frequency line of poles;

a second multiplier means, coupled to the first means for delaying the signal, for creating a real frequency line of zeros; and

where for every pole located left of an imaginary y axis in an s-plane representation, there is a corresponding zero in the right half plane of the s-plane representation at a same imaginary frequency and where the zeros are closer to the imaginary y axis than the poles.

32. A energy dispersive transmission network, comprising:

(A) a notchpass filter means capable of receiving an input signal and generating a first output signal, the notchpass filter comprising a first delay means for creating a

line of poles and zeros, where for every pole located left of an imaginary y axis in an s-plane representation, there is a corresponding zero in the right half plane of the s-plane representation at a same imaginary frequency and the zeros are closer to the imaginary y axis than the poles;

(B) a second delay means capable of receiving the first output signal generated by the notchpass filter means and generating a second output signal; and

(C) a multiplier means for scaling the second output signal according to a gain to generate a third output signal, an energy decay rate of the third output signal relative to the input signal being substantially identical at all frequencies.

33. A method for processing a signal comprising:

(A) providing a notchpass filter comprising:

a first delay module for delaying the signal by a first delay value

a first multiplier for scaling the signal according to a first gain;

a second multiplier for scaling the signal according to a second gain;

the first delay module and first and second multipliers operatively coupled to form a signal processing circuit path; and

(B) supplying signals to first module, and first and second multipliers to process the signal so that the notchpass filter has a comb filter-like amplitude and delay output response characterized by a plurality of peak delay maximum at certain frequencies and decreased gain minimum at the same certain frequencies.

34. The method of claim 33 further comprising:

(C) combining the notchpass filter with an energy transmitting network comprising:

a second module for delaying the signal by a second delay value; and

a third multiplier for scaling the signal according to a third gain; and

the second delay module and third multipliers operatively coupled to form a signal processing circuit path that both delays and scales the signal; and

(D) supplying signals to second module and third multiplier to process the signal so that the combined notchpass filter and energy transmitting network have a comb

filter-like amplitude and delay output response characterized by a plurality of peak delay maximum at the certain frequencies and decreased gain minimum at the same certain frequencies.

35. A method for generating reverberation signals from a signal comprising:

(A) receiving a first plurality of "n" number of input signals representing an input vector;

(B) receiving a second plurality of "m" number of randomization signals, representing a modulation vector, from a source of continuously changing signals;

(C) converting the "m" number of randomization signals into n^2 number of coefficients such that energy in an output vector is substantially identical to energy in the input vector for all possible values of the "m" number of randomization signals; and

(D) multiplying the "n" number of input signals representing the input vector by the plurality of n^2 number of coefficients to generate a plurality of "n" number of product signals representing the output vector.

36. A method of generating, from an input vector representing a signal, an output vector representing a reverberation signal comprising:

(A) providing a source of a plurality of "m" number of randomization signals representing a modulation vector;

(B) receiving a plurality of "n" number of input signals representing the input vector;

(C) converting the "m" number of randomization signals into n^2 number of coefficients such that energy in the output vector is substantially identical to the energy in the input vector for all possible values of the "m" number of randomization signals; and

(D) multiplying the "n" number of input signals representing the input vector by the plurality of n^2 number of coefficients to generate a plurality of "n" number of product signals representing the output vector.

37. The system of claim 36 wherein (A) further comprises:

(A1) providing a plurality of low frequency random phase signal generators.

38. The system of claim 36 wherein (A) further comprises:

(A1) providing a plurality of periodic phase signal generators each having different frequencies.

39. The system of claim 36 wherein (A) further comprises:

(A1) providing a plurality of periodic phase signal generators each having different frequencies and where the phase of only one of the plurality of periodic phase signal generators changes at a given instant and when the phase stops changing another phase signal begins to change.

40. The system of claim 36 wherein (A) further comprises:

(A1) providing a sequencer coupled to the plurality phase signal generators for controlling the stopping and starting of the plurality phase signal generators such that each phase signal changes until reaching a value substantially close to one of 45 degrees, 135 degrees, 225 degrees and 315 degrees and then stops changing and the phase signal of another of the plurality of periodic phase signal generators begins to change.

41. The system of claim 36 wherein (C) further comprises:

(C1) processing each one of the "m" number of randomization signals with a trigonometric function generator so as to generate one of the n^2 number of coefficients such that a trigonometric relationships exists between the one randomization signal and the one coefficient.

42. A signal bearing medium for processing a signal comprising:

logic configured to provide a notchpass filter comprising:

logic configured for a first delay module for delaying the signal by a first delay value;

logic configured for a first multiplier for scaling the signal according to a first gain;

logic configured for a second multiplier for scaling the signal according to a second gain; and

logic configured for the first delay module and first and second multipliers operatively coupled to form a signal processing circuit path; and

logic configured for supplying signals to first module, and first and second multipliers to process the signal so that the notchpass filter has a comb filter-like amplitude and delay output response characterized by a plurality of peak delay maximum at certain frequencies and decreased gain minimum at the same certain frequencies.

43. The signal-bearing medium of claim 47 further comprising:

logic configured for combining the notchpass filter with an energy transmitting network comprising:

logic configured for a second module for delaying the signal by a second delay value; and

logic configured for a third multiplier for scaling the signal according to a third gain; and

logic configured for the second delay module and third multipliers operatively coupled to form a signal processing circuit path that both delays and scales the signal; and

logic configured for supplying signals to second module and third multiplier to process the signal so that the combined notchpass filter and energy transmitting network have a comb filter-like amplitude and delay output response characterized by a plurality of peak delay maximum at certain frequencies and decreased gain minimum at the same certain frequencies.

44. A signal-bearing medium capable of generating reverberation signals from a signal comprising:

logic configured for receiving a first plurality of "n" number of input signals representing an input vector;

logic configured for receiving a second plurality of "m" number of randomization signals, from a source of continuously changing signals, representing a modulation vector;

logic configured for converting the "m" number of randomization signals into n^2 number of coefficients such that energy in an output vector is substantially identical to the energy in the input vector for all possible values of the "m" number of randomization signals; and

logic configured for multiplying the "n" number of input signals representing the input vector by the plurality of n^2 number of coefficients to generate a plurality of "n" number of product signals representing the output vector.

45. A signal-bearing medium capable of generating, from an input vector representing a signal, an output vector representing a reverberation signal comprising:

logic configured for providing a source of a plurality of "m" number of randomization signals representing a modulation vector;

logic configured for receiving a plurality of "n" number of input signals representing the input vector;

logic configured for converting the "m" number of randomization signals into n^2 number of coefficients such that energy in the output vector is substantially identical to the energy in the input vector for all possible values of the "m" number of randomization signals; and

logic configured for multiplying the "n" number of input signals representing the input vector by the plurality of n^2 number of coefficients to generate a plurality of "n" number of product signals representing the output vector.

46. A signal-bearing medium for digitally modulating data representing a signal and for generating reverberation signals representing processed signal data, comprising:

A) logic configured for receiving a first plurality of "n" number of input signals representing an input vector;

B) logic configured for receiving a second plurality of "m" number of randomization signals, from a source of continuously changing signals, representing a modulation vector;

C) logic configured for converting the "m" number of randomization signals into n^2 number of coefficients such that energy in an output vector is substantially identical to the energy in the input vector for all possible values of the "m" number of randomization signals; and

D) logic configured for multiplying the "n" number of input signals representing the input vector by the plurality of n^2 number of coefficients to generate a plurality of "n" number of product signals representing the output vector.

47. The signal-bearing medium of claim 51 wherein (A) further comprises logic configured for providing a plurality of low frequency random phase signal generators.

48. The signal-bearing medium of claim 51 wherein (A) further comprises logic configured for providing a plurality of periodic phase signal generators each having different frequencies.

49. The signal-bearing medium of claim 51 wherein (A) further comprises logic configured for providing a plurality of periodic phase signal generators each having different frequencies and where the phase of only one of the plurality of periodic phase signal generators changes at a given instant and when the phase stops changing another phase signal begins to change.

50. The signal-bearing medium of claim 51 wherein (A) further comprises logic configured for providing a sequencer coupled to the plurality phase signal generators for controlling the stopping and starting of the plurality phase signal generators such that each phase signal changes until reaching a value substantially close to one of 45 degrees, 135 degrees, 225 degrees and 315 degrees and then stops changing and the phase signal of another of the plurality of periodic phase signal generators begins to change.

51. The signal-bearing medium of claim 51 wherein (C) further comprises logic configured for processing each one of the "m" number of randomization signals with a trigonometric function generator so as to generate one of the n^2 number of coefficients such that a trigonometric relationships exists between the one randomization signal and the one coefficient.

52. A computer program product for digitally modulating data representing an audio signal and for generating reverberation signals representing processed audio signal data, the computer program product comprising a computer usable medium having embodied therein computer readable program code comprising:

A) program code for receiving a first plurality of n input audio signals representing an audio input vector;

B) program code for receiving a second plurality of m randomization signals, from a source of continuously changing signals, representing an audio modulation vector;

C) program code for converting the m randomization signals into n^2 mixer coefficients such that energy in an audio output vector is substantially identical to the energy in the audio input vector for all possible values of the m randomization signals; and

D) program code for multiplying the n input audio signals representing the audio input vector by the plurality of n^2 coefficients to generate a plurality of n product audio signals representing the audio output vector.

53. A computer program product digitally filtering data representing an audio signal and generating data representing processed audio signal data, the computer program product comprising a computer usable medium having embodied therein computer readable program code comprising:

i) first delay program code for delaying the audio signal data by a first delay value;

ii) first multiplier program code for scaling the audio signal data according to a first gain coefficient;

iii) second multiplier program code for scaling the audio signal data according to a second gain coefficient;

the first delay program code, and first multiplier program code and second multiplier program code operatively coupled to form a first audio signal processing path, the digital filter having a comb filter-like amplitude and delay output response characterized by a plurality of delay maximum and a plurality of gain minimum at identical frequencies.

54. The computer program product of claim 53 further comprising:

iv) second delay program code for delaying the audio signal data by a second delay value,

v) third multiplier program code for scaling the audio signal data according to a third gain coefficient,

the second delay program code and third multiplier program code operatively coupled to form a second audio signal processing path that both delays and scales the audio signal data.

55. The computer program product of claim 52 further comprising:

program code for resupplying a portion of processed audio signal data to one of the first audio signal processing path and second audio signal processing paths.

56. A data signal embodied in carrier wave useful for digitally modulating data representing an audio signal and for generating reverberation signals representing processed audio signal data, the data signal comprising:

A) program code for receiving a first plurality of n input audio signals representing an audio input vector;

B) program code for receiving a second plurality of m randomization signals, from a source of continuously changing signals, representing an audio modulation vector;

C) program code for converting the m randomization signals into n^2 mixer coefficients such that energy in an audio output vector is substantially identical to the

energy in the audio input vector for all possible values of the m randomization signals; and

D) program code for multiplying the n input audio signals representing the audio input vector by the plurality of n^2 coefficients to generate a plurality of n product audio signals representing the audio output vector.

57. A data signal embodied in carrier wave useful for digitally processing data representing an audio signal and generating data representing processed audio signal data, the data signal comprising:

i) first delay program code for delaying the audio signal data by a first delay value;

ii) first multiplier program code for scaling the audio signal data according to a first gain coefficient;

iii) second multiplier program code for scaling the audio signal data according to a second gain coefficient;

the first delay program code, and first multiplier program code and second multiplier program code operatively coupled to form a first audio signal processing path, the digital filter having a comb filter-like amplitude and delay output response characterized by a plurality of delay maximum and a plurality of gain minimum at identical frequencies.

58. The data signal of claim 57 further comprising:

iv) second delay program code for delaying the audio signal data by a second delay value,

v) third multiplier program code for scaling the audio signal data according to a third gain coefficient,

the second delay program code and third multiplier program code operatively coupled to form a second audio signal processing path that both delays and scales the audio signal data.

59. The data signal of claim 57 further comprising:

program code for resupplying a portion of processed audio signal data to one of the first audio signal processing path and second audio signal processing paths.